(11) (A) No. 1092546

(45) ISSUED 801230

(52) CLASS 204-165

(51) INT. CL.^{2} C25B 9/00

(19) (CA) CANADIAN PATENT (12)

(54) WATER DECOMPOSING APPARATUS

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(21) APPLICATION No. 292,679

(22) FILED 771208

(30) PRIORITY DATE U.K. (51446/76) 761209

No. OF CLAIMS 12

Abstract

A water decomposition apparatus for producing detonating gas or oxyhydrogen gas comprises a plurality of electrolytic cells formed between a nested plurality of endless laminar electrodes each sealingly abutting at its upper and lower edges against elastomeric insulating layers on the surfaces of rigid plates. Electrolyte circulation through the assembly is permitted by an inlet aperture in one extreme cell, an outlet aperture in the other extreme cell and an aperture in each intermediate electrode adjacent its upper edge. The inlet and outlet apertures are coupled for electrolyte circulation by immersing the assembly in electrolyte or by an extended duct system connecting the apertures. Current is supplied to the extreme inner and outer electrodes from a d.-c. source. Control means may be provided to reduce the magnitude of the current as the gas pressure rises. A plurality of assemblies may be connected electrically in series across the d.-c. supply. When an electrode assembly is to be immersed in electrolyte its outermost electrode is surrounded by an electrically inoperative shielding member sealingly engaging the insulating members.

The present invention relates to an apparatus for decomposing water by electrolysis to produce detonating gas (oxyhydrogen gas).

The electrolysis of water produces oxygen and hydrogen by the flow of a DC current. The voltage across a single cell is normally about 2.5 - 3 volts. A DC current of 2390 amperes flowing for one hour will produce 1 centimetre^3 of hydrogen and $\frac{1}{2}$ centimetre^3 of oxygen. Such a high current involves high thermal losses in the electrodes, electrolyte and associated equipment. In order to increase the gas output from a single cell, say to double the gas output, the current must be doubled, but this causes the heat losses to be quadrupled.

It is therefore better, both economically and technically, to connect a plurality of cells electrically in series. However, the current will seek any path ("shunt paths") to avoid passing through all of the cells in turn. In prior art apparatus, such as U.S. patent 3957618, the current follows shunt paths through passages which are provided for the regular supply of electrolyte.

High gas output involves high heat losses. The electrolyte is therefore liable to be overheated and to boil and adequate cooling must be guaranteed, otherwise the corrosive, boiling electrolyte will spill into the gas outlets.

Liquid electrolyte between a pair of electrodes will start to foam as soon as gas is produced in bubbles at the electrode surfaces. These bubbles reduce the conductivity of the electrolyte and this increased

resistance causes higher heat losses. With increasing current (to maintain the gas production), the cell will eventually become filled with foam. This is potentially a situation where the foam might explode. It is essential, in order to prevent this, for the cell to be continually re-plenished with liquid electrolyte.

This invention provides a water decomposition apparatus for producing detonating gas, said apparatus including an electrode assembly comprising:

a nested plurality of tubular laminar electrodes having longitudinal axes extending vertically and each electrode having an endless top edge and an endless bottom edge; a horizontally disposed top plate and a horizontally disposed bottom plate; means sealing the top edges of all said electrodes to said top plate and means sealing the bottom edges of all said electrodes to said bottom plate whereby to form individual cells between each adjacent pair of said electrodes; electrolyte in each of said cells; electrolyte circulation means including an aperture through each electrode, adjacent the top edge thereof, save the extreme innermost and outermost electrodes, an electrolyte inlet aperture formed through said bottom plate into the cell bounded by one of said extreme electrodes and a gas outlet aperture formed through said top plate, from the cell bounded by the other of said extreme electrode;

a direct-current source having positive and negative poles

and means connecting each of said poles to a respective one of said extreme electrodes.

In this apparatus, the level of electrolyte is self-regulating in that the cells will adjust the electrolyte level automatically to the level of the apertures through the electrodes. Gas can pass through these apertures to the gas outlet but no shunt path for current exists through these apertures because they are filled with foam, not electrolyte.

Several of these apparatus may be connected electrically in series.

The apparatus does not need to be contained within a pressure tank because its construction of nested cells provides resistance against internal explosions. Prior art apparatus do require such pressure tanks. Also, the apparatus of the present invention is such that the individual gas volumes are only small so that, if any one of them explodes, the pressure built up is relatively small: moreover, the small explosion cannot pass quickly to other gas volumes. The pressure tanks required by the prior art are heavy and expensive.

Embodiments of this invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a vertical section through one embodiment of apparatus in accordance with the invention;

Figure 2 is a partial sectional plan view of the apparatus of Figure 1, taken along line II-II;

Figure 3 is a schematic diagram illustrating a modification of the apparatus of Figures 1 and 2;

Figure 4 is a schematic diagram illustrating another modification of apparatus in accordance with the invention;

Figure 5 is a schematic diagram illustrating a preferred manner of operating apparatus in accordance with the invention; and

Figures 6 and 7 are schematic perspective representations of modified electrode arrangements for apparatus in accordance with the invention.

The embodiment 10 of the invention which is shown in Figures 1 and 2 comprises a plurality of concentrically disposed electrodes, each of which is a frustum of a hollow cone. In this embodiment there are five electrodes 11 - 15 of which the outermost is surrounded, at least when the assembly is to be operated immersed in electrolyte, by a similar electrically inoperative shielding member 16. The ends of electrodes 11 - 15 and of shielding member 16 abut against resilient insulating and sealing layers 21, 22, formed for example of a natural or synthetic elastomeric material applied to respective rigid support plates 31, 32 which are resiliently urged together by a central bolt or pillar 41 and by a plurality of circumferentially disposed bolts or pillars, of which only three are shown at 42a, b, c, having beneath their clamping nuts 43a-d at their upper ends an appropriate nest of Belville or other spring washers 44a, b, c.

This embodiment of apparatus in accordance with the invention is arranged for immersion in a receptacle containing an electrolyte 50. In Figure 1 only the bottom

of this container is indicated at 51, while the surface of the electrolyte is shown at 52.

In each of the intermediate electrodes 12 - 14 there is provided at least one aperture near its top edge. Such apertures in electrodes 12, 13 and 14 are shown at 60, 61, 62. As the assembly is immersed in the electrolyte, this flows into the space between electrodes 15 and 14 through an inlet aperture 33 provided in lower support plate 31. Upon reaching the level of aperture 62 the electrolyte flows into the space between electrodes 14 and 13, and so on, the displaced air passing out through an outlet aperture 34 provided in upper support plate 32.

Electrical connections to electrodes 11 and 15 are provided by leads 17, 18 respectively which are insulated and which pass sealingly through upper support plate 32 and are taken to a suitable direct voltage source 70 having respective negative and positive terminals 71, 72.

Inlet and outlet apertures 33, 34 of assembly 10 are advantageously provided with respective tubulations 81, 82.

When voltage is first applied to the immersed assembly 10 from source 70 current will initially flow between electrodes 11 and 15 by way of the intervening electrolyte and apertures 60, 61, 62, producing gas mostly at the surfaces of electrodes 11 and 15. Gas produced with the cell 4 formed between electrodes 14 and 15 will collect at the top of the cell and will lower the level of the electrolyte until the gas can escape

through aperture 62 into cell 3 formed between electrodes 13 and 14. The flow of electric current through aperture 62 is now greatly reduced and gas is now generated at electrode 13 as well as at electrode 14. This gas lowers the level of electrolyte in cell 3 in turn, until aperture 61 is no longer immersed, after which gas is generated at both surfaces of electrode 14. The process is repeated in cell 2, so that all of apertures 60, 61, 62 become free of electrolyte and gas is being generated at all the electrode surfaces exposed to the electrolyte.

The generated gas forms with the electrolyte a foam which has an electrical conductivity much lower than that of the liquid electrolyte. The cells may finally contain liquid electrolyte up to only one half of their depth, the remainder of the cell containing electrolyte foam. A circulation of electrolyte foam now commences, foam leaving the assembly by way of outlet aperture 34 and fresh electrolyte entering through inlet aperture 33. The rate of circulation increases with the rate of gas production.

It may also be found advantageous in some circumstances to arrange that the centres of the apertures in adjacent electrodes are aligned upon a common line which may be inclined to the horizontal. In Figure 1 the holes 60, 61, 62 are aligned upon a centre-line 63 inclined upwardly in the direction of electrolyte circulation. In some embodiments this centre-line may be horizontal, or even inclined downwardly.

It may be found advantageous to displace the

apertures in adjacent electrodes from direct alignment with one another as illustrated in Figure 1 so as to increase the length of the initial leakage path. The foam path between openings not directly aligned or facing each other is longer, and therefore the foam has more time to liberate gas and again form a partly liquid electrolyte while still within the cell. This in turn helps to keep the liquid level in cells 1, 2, 3 and 4 at a higher level. This is important when the rate of gas generation is required to be as high as possible and avoids the risk of a cell being wholly depleted of electrolyte by too high a rate of foam production. An increased amount of foam in a cell increases the cell resistance and thus reduces the current passing through the whole apparatus and lowers the rate of gas generation, which is proportional to current and hence to reduce the delay in coming into full gas production.

Although the illustrated embodiment described above includes only five electrodes, a practical embodiment may contain as many as 30 electrodes, the radial width of the cells being for example 5mm and the height of the electrodes (distance between support plates) being for example 100 mm. The current applied to the apparatus from source 70 should be adjusted to a value such that the cells do not become wholly empty of electrolyte owing to too high a rate of gas production.

It is not necessary for the electrode assembly described in relation to Figures 1 and 2 to be immersed in bulk electrolyte as described above. An alternative

arrangement, illustrated by Figure 3, may be employed in which the inlet and outlet tubulations 81, 82 of an assembly 10 generally as described in relation to Figures 1 and 2 are connected to opposite ends of a system of pipes containing the electrolyte. Outlet tubulation 82 is extended to form a conduit leading sealingly into a reservoir 90, closed at its upper end by a screwed-on cover 91 and provided with a gas outlet conduit 92 through which the generated gas is taken for use. The bottom of reservoir 90, in which the electrolyte collects as gas escapes from foam introduced into the reservoir through conduit 82, is connected to inlet tubulation 81 by way of an extended cooling pipe or worm 93. Preferably the volume of electrolyte initially contained in the apparatus is sufficient to permit continuous gas generation for a prolonged period, such as eight hours. The electrolyte must be replenished with water from time to time, the amount required to be added corresponding to the volume of gas generated.

As in the arrangement of Figures 1 and 2, the innermost and outermost electrodes are connected by way of leads 17, 18 to the terminals of a direct-current source 70.

This modified arrangement is simpler to construct that that of Figures 1 and 2, in that a moulded or welded gas-tight tank large enough to accept the electrode assembly is not essential and only known pipe fittings are required for the electrolyte system.

The arrangements described with reference to

Figures 1 - 3 require to be energised by a direct-current supply providing approximately 2-3 volts per cell of the electrode assembly. Since constructional problems limit the number of electrodes that can conveniently be used in one assembly to at most 30, the maximum voltage that can be applied to the apparatus is 90V, so that when the apparatus is to be energized from the public a.-c. supply a transformer is necessarily used to reduce the alternating voltage before rectification.

This difficulty may be overcome by using a plurality of electrode assemblies electrically connected in series. For a 220V a.-c. supply, which may be rectified by a normal bridge rectifier to yield a 220V d.-c. supply, it is convenient to use three electrode assemblies connected electrically in series and each including 24 cells or 25 electrodes. With such an arrangement the directly-rectified supply voltage may be employed to energize the apparatus.

An arrangement of the kind described above is illustrated by Figure 4, which shows an apparatus 100 consisting of a closed container 52 provided with a gas outlet pipe 53 and a normally-sealed filling aperture 54 closed by a screw-on cover 55. This container is largely filled with electrolyte 50, in which are immersed three similar electrode assemblies 10<u>a</u>, 10<u>b</u>, 10<u>c</u>, each of the construction described in relation to Figures 1 and 2, but including 25 nested electrodes and hence requiring to be energized by a direct-current supply at a maximum of 75 volts. The three electrode assemblies are electrically connected in series across the output

of a bridge rectifier 71 fed from the 220V public a.-c. supply 72 by insulated leads 17, 18, 19, 20.

It will be understood that when an apparatus as described above with reference to Figure 4 is in use, passing a current of, for example, 15 amperes, the amount of gas generated will correspond to that which would be produced by a current of (75 x 15) = 1125 A flowing in a single cell fed at 3V d.-c. for which the losses in the necessary transformer, high-current rectifiers and electrical conductors would be very much higher. With this alternative arrangement would also require forced circulation of the electrolyte through a cooler or cooling fins on the electrolyte tank to remove the heat generated in the cell.

Arrangements in accordance with the invention avoid the necessity for forced electrolyte circulation and also enable the electrical losses to be kept relatively low.

When multiple electrode assemblies are used it is alternatively possible, instead of immersing them in a common tank as described in relation to Figure 4, to provide each electrode assembly with its own individual electrolyte circulatory system as described in relation to Figure 3, so that each assembly would produce circulation and cooling of its own electrolyte.

It is desirable in every embodiment to provide suitable means for controlling the magnitude of the current applied to the electrode system. This, may, of course, be effected by known means such as tapped transformers and resistors. It is however preferred to

provide for automatic regulation of the current. This may be effected as will be described with reference to Figure 5.

In Figure 5 an apparatus 100 of the kind described in relation to Figure 4 is arranged to be fed from a rectifier energized by a 220V a.-c. supply 72. In this embodiment, however, the passage of current from the supply 72 to the rectifier 71 is controlled by a known triac or thyristor control unit 73 in which the duty cycle of the control elements (triacs or thyristors) is determined by a triggering unit 74 responsive to a control signal, representative of the pressure in the gas outlet pipe 53 of apparatus 100, which is developed by a known pressure transducer 75 coupled to pipe 53.

It will be understood that in any of the embodiments it may be arranged that the magnitude of the current supplied to the electrodes may be controlled in accordance with the pressure of the generated gas. The means for producing this result in the different embodiments differ from that described in relation to Figure 5 only in ways which will be fully apparent to those skilled in the art of feedback controls.

The particular form of electrodes illustrated in the foregoing embodiments is not an essential feature of the invention. The essential feature is that each electrode is formed by a laminar member surrounding an area and conveniently substantially equidistant from any adjacent inner or outer electrodes. However, it is not essential for the electrodes to be uniformly spaced.

The outer electrodes are of larger area than the inner electrodes and since the same current flows in each cell the current density in the outer cells is lower. The amount of gas generated per unit volume of cell is therefore also lower if the interelectrode spacing is the same. It is therefore possible to reduce the interelectrode spacing in the outer cell, that is, the spacing between electrodes may be reduced as their diameter increases. The form of all the individual electrodes of any assembly is preferably geometrically similar. For example, Figure 6 shows some electrodes 111-114 of an assembly in which each electrode has the form of an endless wall or hollow parallelepiped. The intermediate electrodes 112, 113 are pierced by holes 60, 61 equidistant from their upper edges. Figure 7 shows part of an assembly of electrodes each of which is of the form of a hollow right cylinder, the intermediate electrodes 122, 123 being pierced by holes 64, 65 which are equidistant from the upper edges of the respective electrodes but are not circumferentially aligned, but are instead mutually angularly displaced by 180° though some other angle may be chosen if preferred.

In the case of embodiments as described in relation to Figures 1 and 2 the electrode assembly need not be wholly immersed in electrolyte. It is only necessary for the level of the electrolyte to be not lower than the uppermost of the holes pierced in the electrodes, so as to ensure that the electrolyte will enter all of the cells.

WHAT I CLAIM IS:

1. A water decomposition apparatus for producing detonating gas, said apparatus including an electrode assembly comprising:

a nested plurality of tubular laminar electrodes having longitudinal axes extending vertically and each electrode having an endless top edge and an endless bottom edge;

a horizontally disposed top plate and a horizontally disposed bottom plate;

means sealing the top edges of all said electrodes to said top plate and means sealing the bottom edges of all said electrodes to said bottom plate whereby to form individual cells between each adjacent pair of said electrodes;

electrolyte in each of said cells;

electrolyte circulation means including an aperture through each electrode, adjacent the top edge thereof, save the extreme innermost and outermost electrodes, an electrolyte inlet aperture formed through said bottom plate into the cell bounded by one of said extreme electrodes and a gas outlet aperture formed through said top plate from the cell bounded by the other of said extreme electrode;

a direct-current source having positive and negative poles and means connecting each of said poles to a respective one of said extreme electrodes.

2. A water decomposition apparatus as claimed in claim 1, wherein said extreme outermost one of said electrodes is surrounded by a tubular laminar member sealingly engaging said top and bottom plates.

3. A water decomposition apparatus as claimed in claim 2, and further including a tank enclosing said electrode assembly and electrolyte in said tank and immersing said electrode assembly.

4. A water decomposition apparatus as claimed in claim 1, wherein said inlet and outlet apertures are coupled for liquid circulation therebetween by an extended duct containing said electrolyte and provided with an outlet means for gas generated in said electrode assembly.

5. A water decomposition apparatus as claimed in claim 1 and including a plurality of said electrode assemblies, said assemblies electrically connected in series across said direct-current source.

6. A water decomposition apparatus as claimed in claim 5, wherein said plurality of electrode

assemblies are enclosed in a common tank and immersed in electrolyte.

7. A water decomposition apparatus as claimed in claim 5, wherein said inlet and outlet apertures of each of said electrode assemblies are individually coupled for liquid circulation therebetween by a respective extended duct containing said electrolyte and provided with an outlet means for gas generated in said electrode assembly.

8. A water decomposition apparatus as claimed in claim 1, wherein said direct-current source is energized from an alternating current.

9. A water decomposition apparatus as claimed in claim 8, wherein said direct-current source is a rectifier energized directly by said alternating current supply.

10. A water decomposition apparatus as claimed in claim 1, and including control means responsive to increasing pressure of gas generated by said apparatus to reduce the magnitude of the applied electric current.

11. A water decomposition apparatus as claimed in claim 1, wherein each of said electrodes has the

form of a hollow parallelepiped or surface of revolution.

12. A water decomposition apparatus as claimed in claim 1, wherein each said sealing means comprises a layer of elastomeric material applied to the respective said plate.

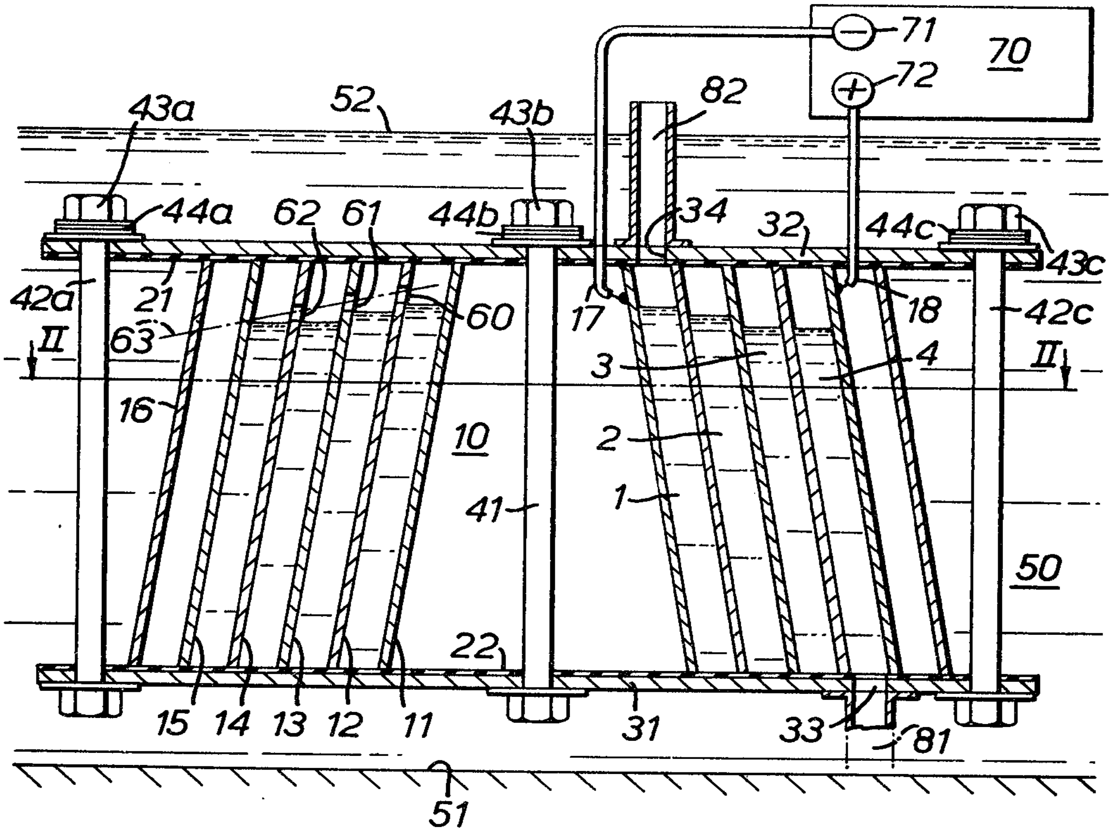

FIG.1.

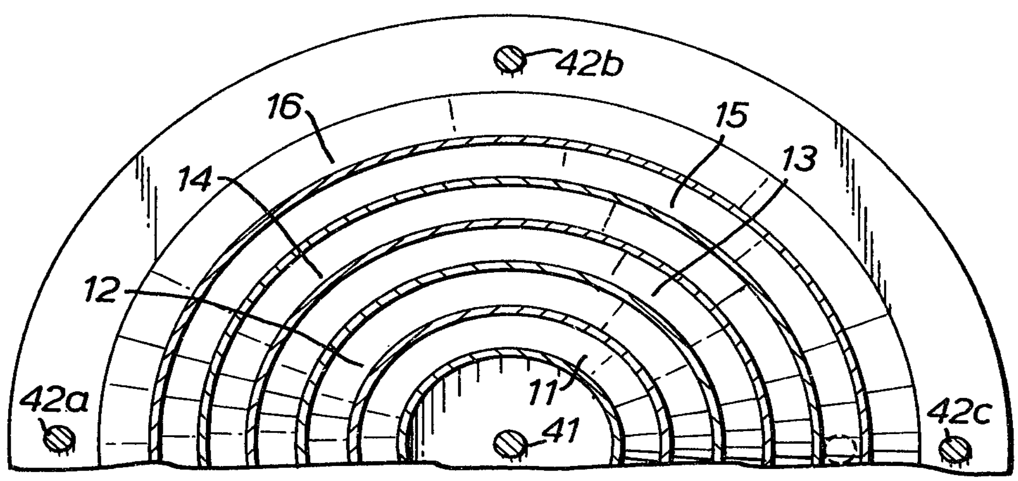

FIG.2.

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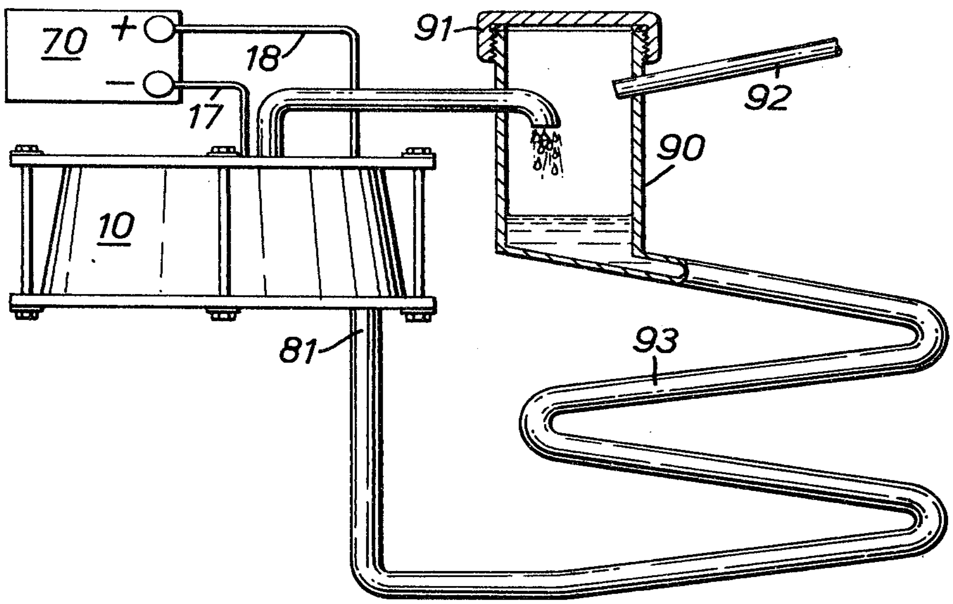

FIG.3.

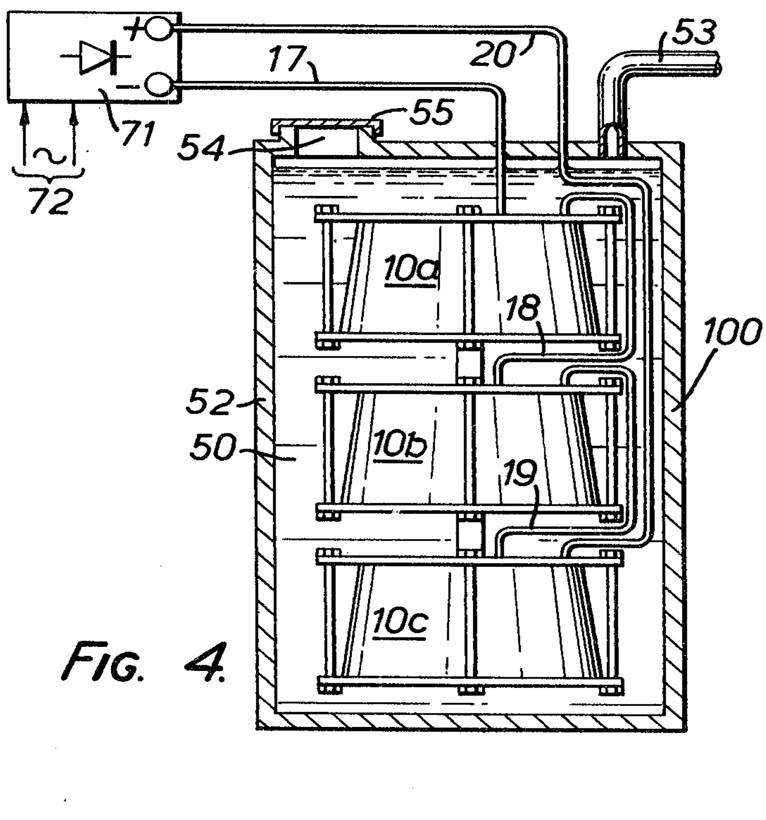

FIG. 4.

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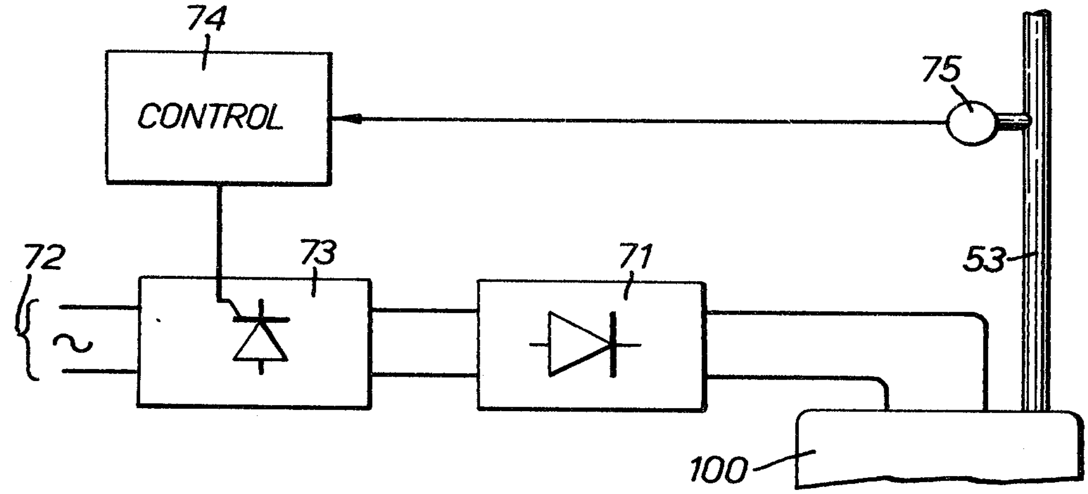

FIG.5.

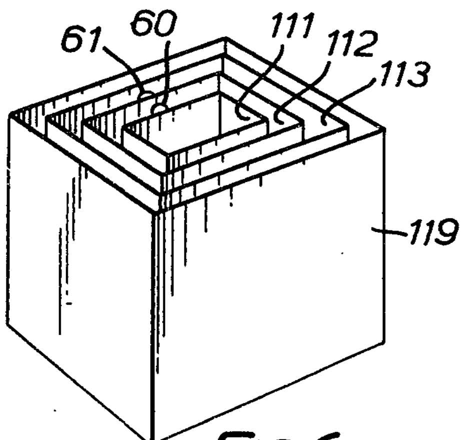

FIG.6.

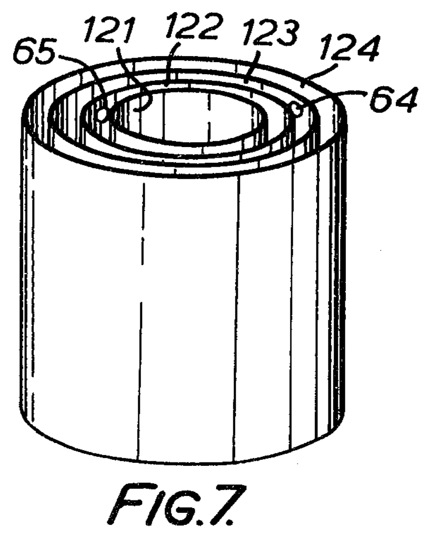

FIG.7.

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